Capacitance	**Capacitors - charge storage and discharging**

Learning objectives	**MUST (C)**	Explain how and why the rate of charge loss varies in a discharging capacitor
	SHOULD (B)	Define the time constant, and state the equations used to explain charge, p.d. and current decay
	COULD (A/A*)	Apply the equation to calculate charges, p.d. or currents in a discharging capacitor

STARTER: Every year, approximately 30,000 people in the UK suffer a sudden cardiac arrest in public. If a defibrillator is used, survival rates go up from 28% to >80%. Defibrillators use a capacitor to store charge, which is released as a shock. The capacitance in one model is 32 μF and the charge that builds on each plate is 160 mC. What is the p.d. across the plates?

EXTENSION:
How is this possible with mains electricity, and what safety precautions should be taken?

0:04:00

$$C = Q/V$$

$$V = Q/C$$

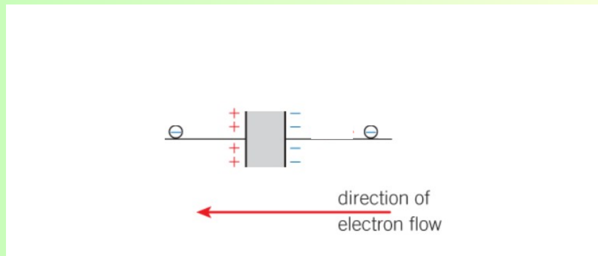
$$V = 160 \times 10^{-3}\ C / 32 \times 10^{-6}\ F$$

$$V = 5000\ V$$

Capacitance	**Capacitors - charge storage and discharging**
MUST (C)	Explain how and why the rate of charge loss varies in a discharging capacitor

Recall: Why does a capacitor store energy? Explain, using the diagram.

Does this vary during the charging process? Explain why, or why not.



Now explain what will happen when a capacitor **discharges**.

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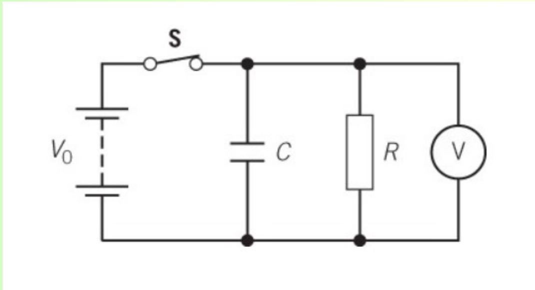
Oct 16-21:59

Capacitance	**Capacitors - energy storage and discharging**
SHOULD (B)	Explain how and why the rate of charge loss varies in a discharging capacitor

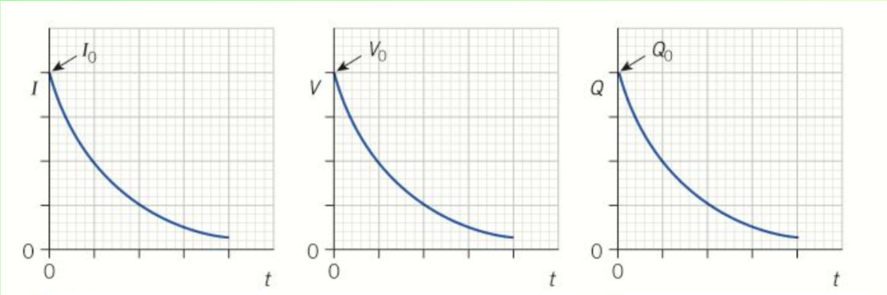
When the switch S is closed, the capacitor charges. When S is opened, the capacitor discharges through the resistor.



We can work out that the rate of charge decay won't be constant.

Initially, charge storage is very high and the p.d. across C is high. A large current will flow and so charge loss will be very quick.

As the capacitor loses charge, the p.d. will fall. The lower the p.d., the lower the current and so the slower the rate of charge loss.



$I = I_0 e^{-\frac{t}{CR}}$ $V = V_0 e^{-\frac{t}{CR}}$ $Q = Q_0 e^{-\frac{t}{CR}}$

I_0, V_0 and Q_0 are initial values.

Capacitance	**Capacitors - energy storage and discharging**
COULD (A/A*)	Define the time constant, and calculate charges at different times for a given discharging capacitor

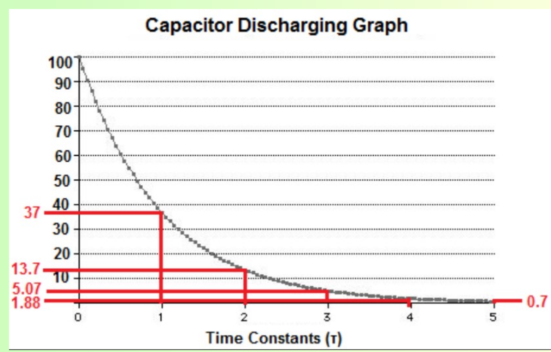
$$Q = Q_0 e^{-\frac{t}{CR}}$$

When t = CR, the equation reads: $$Q = Q_0 e^{-1}$$

e^{-1} is approx. 0.37; so at t = CR $$Q = 0.37Q_0$$

We call CR the time constant. You can choose any starting point in the discharge process: CR seconds later, the charge will have dropped to 0.37 of the value at that starting point.

The graph on the right (which could be for V, I or Q) shows that in every time constant period, the value depletes by 63% (or can be multiplied by 0.37)



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Capacitance	**Title**
COULD (A/A*)	Define the time constant, and calculate charges at different times for a given discharging capacitor

$$Q = Q_0 e^{-\frac{t}{CR}}$$

We can use natural logarithms (ln) to help us solve these equations.

$$\frac{Q}{Q_0} = e^{-\frac{t}{CR}}$$

$$ln\left(\frac{Q}{Q_0}\right) = -\frac{t}{CR}$$

0:05:00

Kilo 10^3 Complete summary questions for section 21.4

Mega 10^6 Complete worksheet 129-5

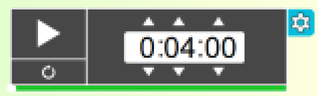
Giga 10^9 Complete worksheet 129-6

Capacitance	**Capacitors - charge storage and discharging**

Learning objectives	**MUST (C)**	Calculate the charge stored in a capacitor
	SHOULD (B)	Explain how and why the rate of charge loss varies in a discharging capacitor
	COULD (A/A*)	Define the time constant, and calculate charges at different times for a given discharging capacitor

PLENARY: The capacitance in the defibrillator in our starter is 32 μF. If the path resistance through a patient's body is 1000 Ω, how long does it take for 95% of the initial charge of the defibrillator to decline?

EXTENSION:
Some defibrillators have gel in between the defibrillator and the patient's skin. If this gel is omitted, what effect might this have?



$$ln\left(\frac{Q}{Q_0}\right) = -\frac{t}{CR}$$

$-t = \ln(0.95) \times CR$

$= \ln(0.95) \times 32 \times 10^{-6} \times 1000$

$= 1.64$ ms

May 3-15:02